feedstock production for bioethanol

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I. Introduction

Sweet sorghum is similar to grain sorghum but possesses sugar-rich stalks, with higher juice content. Because of its rapid growth, high sugar accumulation, high biomass production potential and wider adapt ability, sweet sorghum can be grown in different agro-climatic conditions. The sugar content in the juice extracted from sweet sorghum varies from 16-23% Brix. It has good potential for jaggery and syrup production besides ethanol. The grain can be used as food and the bagasse after extraction of juice from stalks is an excellent livestock feed. The potential food vs. fuel conflict from the diversion of crop land for cultivation of 'bioethanol' crops does not arise with sweet sorghum as it meets the multiple requirements the food, fuel and fodder.

In view of the potential benefits of sweet sorghum as a feedstock for bioethanol production, a pilot value chain model of sweet sorghum as a food-feed-fodder-fuel was tested in Andhra Pradesh, India, to augment incomes of farmers while developing a sustainable sweet sorghum–ethanol value chain under ICRISAT-NAIP (ICAR) Sweet Sorghum Value Chain Project by linking sweet sorghum farmers to ethanol industry.

The economic analysis of sweet sorghum cultivation for ethanol production was carried out under two different production systems: centralized and decentralized. The economic analysis in this chapter will provide evidence on the competitiveness of sweet sorghum as an alternative crop in the farmers' fields. The rationale for developing two different models for linking sweet sorghum farmers to bioethanol industry economics of sweet as a feedstock for ethanol production are discussed in other chapters in this book.

Based on the real time data available from the farmers' fields from pilot testing sites/clusters, the cost of production of sweet sorghum was collected along with similar costs for competing crops that sweet sorghum could replace (partially). The data on cost of conversion to ethanol from both the centralized

model (stalks' juice converted to ethanol) and decentralized systems (syrup converted into ethanol) are analyzed and presented in other chapters in this book.

II. Data source, sampling framework and methodology

The primary source of data was the farmers cultivating sweet sorghum under the project. Detailed and structured farm survey instruments were developed to elicit information from farmers on the cropping pattern, production practices of sweet sorghum, utilization of grain and stalk, farmers' perceptions on growing sweet sorghum vis-à-vis other competing crops and input-output relationships. Data on constraints to growing sweet sorghum and competing crops (technology related) and postharvest constraints were also collected. The primary data on sweet sorghum cultivation under centralized locations was collected for the crop year 2007-08 from Daultabad cluster in Medak district of Andhra Pradesh, while for the decentralized locations, data was collected for the crop years 2008-09, 2009-10 and 2010-11 from Ibrahimbad village in Medak district of Andhra Pradesh. The details on the number of sample farmers and number of villages selected for data collection is presented in Table 1. Standard random sampling procedures were used to draw sample of farmers from the selected villages. While sampling, adequate representation was given to include small, medium and large farmers based on size of landholdings.

Table 1. Sweet sorghum sample size year-wise under centralized and decentralized locations, Medak districts, Andhra Pradesh.

Indicator	Centralized	Decentralized		
	2007	2008	2009	2010
Number of villages	5	9	11	11
Number of sample farmers	64	29	45	49

The data collected was analyzed for various costs, gross and net returns and input-output ratios of the crops. The costs of cultivation that were covered include both paid-out costs and imputed costs. Paid-out costs included hired labor (human, animal and machinery); expenses on material inputs such as seed, fertilizer, manure, pesticides and irrigation; and rent paid for leased-

in land. Since some of the inputs used in the production process came from family sources, the value of these inputs was imputed. The method of imputing these costs was on the basis of the prevailing market rates for labor and materials and postharvest prices of the main product and by-product. However, in calculating the net returns to crop cultivation only cost concept A1 was considered, ie, the value of paid-out costs such as hired labor and expenses on materials while the imputed cost of family labor was not included. All the costs and returns were based on the actual area reported by the farmers. Yields were calculated based on the measured area that was found to be less in most cases compared to the actual area reported by the farmers. For the purpose of this analysis actual area reported by farmers was considered.

III. Economics of sweet sorghum cultivation – Centralized operations

In the centralized system, the farmers were directly linked to the distillery for supply of sweet sorghum stalk. Under the centralized operations, during rainy season of 2007, a cluster of villages in Medak district, Daultabad Mandal, Andhra Pradesh, in the radius of 50 km from the distillery covering an area of 538 hectares targeting 791 farmers growing NTJ variety of sweet sorghum was taken up by Rusni Distilleries Pvt. Ltd. The distillery had entered into a buy-back agreement with farmers to purchase the stalks at an agreed price. A local NGO acted as an intermediary between Rusni and the growers for providing seed, technical backstopping and ensuring timely delivery of stalks to industry and payments to farmers. The NGO was also liaising with research organizations for providing the latest technology and technical backstopping related to crop production.

1. Costs

The sum of all costs (labor and materials) per hectare of sweet sorghum was Rs 11,510 during 2007. Costs incurred in fertilizing the field and in intercultivation and weeding account for the largest share at 18% each. Farmyard manure (FYM) was the next most expensive component accounting for 17% of the total expenses. Harvesting and threshing accounted for 15% of the total expenses (Fig. 1).

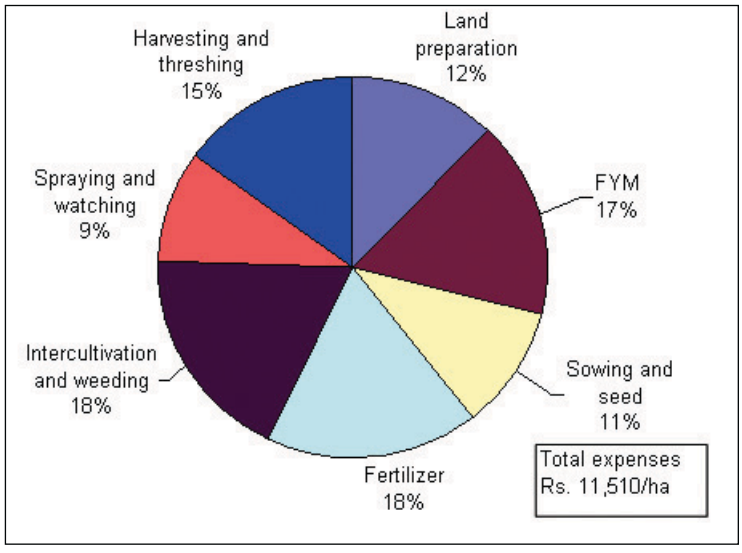

Fig. 1. Activity-wise break up of cost of cultivation for sweet sorghum.

2. Returns

The net revenue for the marginal farmers was Rs 2,986 ha^{-1}, for the small farmers it was Rs 3,514, and for the medium farmers it was Rs 3,897 ha^{-1} (Table 2). While there was not too much of a difference in the gross revenue and costs, net revenues increases marginally with the landholding size. There were no specific reasons for the increasing net revenues as we moved up the landholding class, except that the small and medium farmers seemed to have waited for the crop to fully mature prior to harvesting and thus harvested more grains compared to the marginal farmers.

There was considerable variation in the net revenues for sweet sorghum-based on the soil type it was grown. Net revenue for farms with shallow red soil was Rs 3,624 ha^{-1}, for deep red soils Rs 2,089 ha^{-1}, for medium to shallow black soils was Rs 2,418 ha^{-1}, and for medium black soils it was 4,116 ha^{-1} (Table 3). The break-even yield was 24.13 t ha^{-1} of stalk priced at Rs 600 t^{-1}. Twenty six farmers (13%) achieved stalk yields higher than the break-even yields.

Table 2. Summary of sweet sorghum cost of cultivation according to landholding class, 2007.

Category	All categories	Marginal	Small	Medium
Grain yield (kg ha^{-1})	346	255	449	299
Grain value (Rs ha^{-1})	2,214	1,617	2,865	1,912
Stalk yield (q ha^{-1})	141	150	136	145
Stalk value (Rs ha^{-1})	8,504	9,009	8,170	8,714
Gross income (Rs ha^{-1})	10,718	10,626	11,036	10,626
Total expenses excluding family labor (Rs ha^{-1})	7,719	7,641	7,522	6,729
Net revenues (excluding family labor) (Rs ha^{-1})	2,999	2,986	3,514	3,897

Note: Marginal farmers, n=21; Medium farmers, n=1; Small farmers, n=28. Large farmers included in all categories.

Table 3. Summary of sweet sorghum cost of cultivation by soil type, 2007.

Category	All soil types	Shallow red soils	Deep red soils	Medium to shallow black soils	Medium black soils
Grain yield (kg ha^{-1})	346	366	141	272	389
Grain value (Rs ha^{-1})	2,214	2,447	988	1,840	2,398
Stalk (q ha^{-1})	142	147	136	146	155
Stalk value (Rs ha^{-1})	8,504	8,821	8,187	8,788	9,428
Gross income (Rs ha^{-1})	10,718	11,268	9,174	10,628	11,826
Total expenses excluding family labor (Rs ha^{-1})	7,716	7,643	7,086	8,211	7,710
Net income (excluding family labor)	3,002	3,624	2,089	2,418	4,116

Note: Shallow red soils, n=28; Deep red soils, n=3; Medium to shallow black soils, n=8; Medium black soils, n=25.

3. Competitiveness of sweet sorghum for cultivation: Centralized operations

The cropping pattern of the sample farmers showed that the main competing dryland crop is maize. Maize was either sole cropped or intercropped with

pigeonpea. Detailed cost of cultivation data was elicited from 29 farmers growing a sole crop of maize and 13 farmers growing maize intercropped with pigeonpea in order to gauge the competitiveness of sweet sorghum vis-à-vis maize.

Table 4 shows the costs and revenues of maize cultivation. The average net revenue for sole cropped maize was Rs 7,396 ha^{-1} which was higher than that for sweet sorghum. The total costs of maize cultivation were also higher compared to sweet sorghum at Rs 9,386 ha^{-1}, as also the gross revenue at Rs 16,782 ha^{-1}.

Table 4. Costs and revenues from maize cultivation, 2007.

Category	Value
Grain yield (kg ha^{-1})	2,434
Grain value (Rs ha^{-1})	15,855
Fodder yield (t ha^{-1})	35
Fodder value (Rs ha^{-1})	927
Gross income (Rs ha^{-1})	16,782
Total expenses (Rs ha^{-1})	13,306
Total expenses excluding family labor (Rs ha^{-1})	9,386
Net income excluding family labor (Rs ha^{-1})	7,396
Number of households	29

The average net revenue from maize intercropped with pigeonpea was higher than both sweet sorghum and the sole maize at Rs 10,137 ha^{-1}. Total expenses for this cropping system were lower than the sole cropped maize system at Rs 8,330 ha^{-1}, while gross revenue was much higher at Rs 18,466 ha^{-1} (Table 5).

Table 5. Costs and revenues of maize intercropped with pigeonpea.

Category	Value
Maize grain yield (kg ha^{-1})	1,938
Maize grain value (Rs ha^{-1})	12,438
pigeonpea (kg ha^{-1})	285
pigeonpea value (Rs ha^{-1})	4,8967
Maize fodder yield (q ha^{-1})	37
pigeonpea fodder yield (q ha^{-1})	8
Total fodder value (Rs ha^{-1})	1,132
Gross income (Rs ha^{-1})	18,466
Total expenses (Rs ha^{-1})	13,094
Total expenses excluding family labor (Rs ha^{-1})	8,329
Net income excluding family labor (Rs ha^{-1})	10,136
Number of households	13

A cropping system-wise comparison of total expenses (excluding family labor) and gross revenues is shown in (Fig. 2). The most probable reasons of sweet sorghum performing relatively poorly compared to competing crops are:

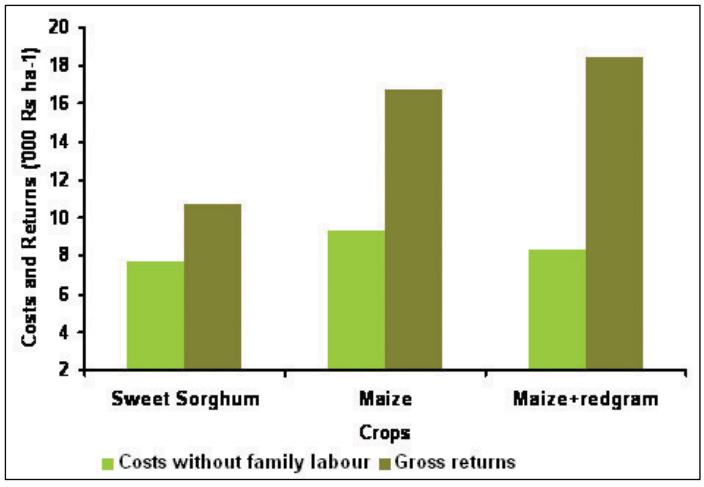

Fig. 2. Crop-wise cost of cultivation (excluding family labor) and gross revenues.

- The supply of only one variety of sweet sorghum to the farmers (suitable hybrids for the farmers' fields not made available).
- The variability of the quantity and quality of the seed supplied to the farmers.
- Farmers are not fully aware of the full range of practices.
- Harvest window not staggered.
- Grain maturity and yield compromised.

4. Farmers' perception of sweet sorghum cultivation

A greater proportion of small and medium farmers grew sweet sorghum when compared to the large and marginal farmers. Supply of inputs on credit basis, low cost of cultivation, low risk and short duration of the sweet sorghum crop compared to maize, were cited as the main reasons for growing sweet sorghum. However, only 38% of households who grew sweet sorghum were interested in expanding the area under sweet sorghum in the coming years. Of these households 55% stated that they would replace maize with sweet sorghum, while 21% of households would expand the area under sweet sorghum in fallow lands. The main reason that was given for planting sweet sorghum in the coming years was the availability of inputs on credit. The

prospect of income from the sale of both grain and stalk as well as the lower cost of cultivation and lower risk were also strong incentives that guided the respondents to state that they would be planting sweet sorghum in the coming years. There was also a perception that there would be fewer attacks by wild boars. 53% of households who grew sweet sorghum were not interested in increasing the area mainly due to non-availability of dryland and was less profitable than other crops, such as maize. The remaining 9% did not respond to this question.

IV. Economics of sweet sorghum cultivation – Decentralized system

As mentioned, to overcome some of the shortfalls of the centralized unit system where it was found that delays in transporting stalk to industry resulted in loss of juice yield and hence its area of procurement of stalk would have to be restricted to farmers close to the industry, a decentralized crushing unit was set up at Ibrahimabad village, Medak district, on a pilot basis. The decentralized unit model was experimented with wherein the stalk will be crushed close to the villages where it is grown and the juice is converted into syrup and stored in cans. The syrup is transported to the ethanol industry for further processing into ethanol. The main advantage of this model is that the syrup can be stored for 6-8 months before it is converted into ethanol thus allowing flexibility in transportation and conversion into ethanol.

Accordingly, the area under cultivation, input supply, production (grain and stalk), gains in productivity, cost, returns, gains in productivity were monitored and recorded for the agricultural years 2008-09, 2009-10 and 2010-11 for economic analysis.

1. Cost of Cultivation

In 2008, total cost of cultivating sweet sorghum was Rs 15,804 ha^{-1}(including family labor). Land preparation and composting with 26% was the highest component of cost of cultivation of sweet sorghum followed by harvesting and threshing activity with 22%. Among resources utilized for cultivation of sweet sorghum, human labor with 56% was the highest resource component followed by bullock labor with 19%. However, the cost of cultivation both for 2009 and 2010 declined by 27 and 21% respectively compared to 2008. In

2008 besides FYM farmers applied tank silt supplied by the government, but incurred labor cost for spreading the silt. In 2009 and 10, cost of FYM came down since no tank silt was applied. The cost of cultivating sweet sorghum was Rs 11,502 ha^{-1} during 2009 and Rs 12,414 ha^{-1} for 2010. The activity-wise break-up of cost for 2009 and 2010 presents similar findings of that observed during 2008 (Table 6). The inputs utilization for cultivation of sweet sorghum for all the three agricultural years is presented in Table 7.

Table 6. Activity wise costs break-up (% share) for sweet sorghum cultivation, Ibrahimbad.

Variables	2008	2009	2010
Land preparation + Compost	26.5	16.6	19.3
Ploughing/Sowing	12.6	21.3	16.5
Fertilizer	14.8	17.7	22.5
Interculture, weeding & thinning	17.6	20.6	22.9
Watching & irrigation	6.2	1.0	1.3
Harvesting & Threshing	22.3	22.8	17.5
Total	100.0	100.0	100.0

Table 7. Input utilization of sweet sorghum, Ibrahimbad, Medak, Andhra Pradesh.

		Year		
		2008	**2009**	**2010**
Inputs utilized (ha^{-1})				
Labor (days)	Male Hired	15	10	9
	Male Family	25	8	6
	Female Hired	45	38	30
	Female Family	28	15	13
Bullock pair (days)	Hired	3	8	4
	Own	9	3	4
Tractor (hr)	Hired	7	2	7
	Own	0	0	0
FYM (kg)	Own	1800	800	600
	Buy	100	200	300
Seed (kg)	Own	0	0	0
	Buy	7	5	6
Total fertilizer (kg)		275	257	280
Irrigation/machinery (hr)		1	0	
Thresher (days) (hired & family)		0	0	3

2. Returns to cultivation

The net returns realized in cultivation of sweet sorghum excluding family labor was Rs 6,490 ha^{-1} during 2008. Net returns excluding family labor obtained from sweet sorghum was negative by Rs 441 ha^{-1} during 2009 due to dry spell after one month of sowing. In addition, earheads were also not harvested therefore no additional income from grains resulting in negative returns being realized. Net returns further declined to Rs 1833 ha^{-1} during 2010 due to heavy rains before harvest leading to loss in both stalk and grain yields (Table 8). However, in 2011 farmers obtained positive net returns of around Rs 1500 ha^{-1} due to better climatic conditions. The final analysis is not yet complete.

Table 8. Gross and net returns to cultivation of sweet sorghum, Ibrahimbad, Medak, Andhra Pradesh.

Indicators	Year		
	2010	2009	2008
Stalk quantity (t ha^{-1})	6.7	14	18
Stalk price (Rs t^{-1})	800	700	600
Grain (kg ha^{-1})	301	119	954
Grain price (Rs kg^{-1})	8	7	8
Gross income (Rs ha^{-1})	7,664	10,530	18,255
Total costs excluding family labor (Rs ha^{-1})	9,496	10,971	11,765
Net returns excluding family labor (Rs ha^{-1})	(1,833)	(441)	6,490

3. Competitiveness of sweet sorghum for cultivation - Decentralized operations

Net returns excluding family labor obtained from sweet sorghum was the highest among rainfed competing crops in Ibrahimbad during 2008. Returns realized from sorghum + pigeonpea intercrop was the next highest with Rs 4,309 ha^{-1} followed by maize + pigeonpea with Rs 3,567 ha^{-1} and Rs 3,466 ha^{-1} for maize. However, during 2009 and 2010 net returns obtained were negative for sweet sorghum and its competing crops due to adverse climatic conditions during sowing and harvesting stages in Ibrahimbad. The net returns for competing crops was more negative for sorghum + pigeonpea intercrop at Rs (5403 ha^{-1}) compared to sweet sorghum at Rs (1833 ha^{-1}) during 2010.

The benefit-cost presented in Table 9 indicated sweet sorghum had better ability to withstand adverse climatic conditions since the loss incurred by

sweet sorghum was only - 0.19 compared to sorghum–pigeonpea intercrop at -0.41 while maize was marginally better by -0.03.

Table 9. Benefit-Cost ratio of sweet sorghum and competing crops, Ibrahimbad.

Crop	2008	2009	2010
Sweet Sorghum	1.55	0.96	0.81
Maize–Pigeonpea	1.30	NA	0.97
Sorghum–Pigeonpea	1.37	0.97	0.59

V. Conclusions

Cultivation of sweet sorghum under centralized operations has shown that it is profitable even with the existing yield levels of 14-15 t ha^{-1} which are considered to be low when compared to farm trials which range between 30-40 t ha^{-1}. In comparison to grain sorghum, sweet sorghum is definitely profitable. Grain sorghum and sweet sorghum returns were compared outside the cluster villages since within the cluster not many farmers were growing sorghum. In comparison to competing crops like sole maize and maize intercropped with pigeonpea under rainfed conditions, the net returns are marginally better for sweet sorghum in a few years and for maize in another year. However, since there is significant scope for yield potential to be realized under farm conditions and with the improvement in technology and improved agronomic practices (farmers are still not fully conversant with the practices for a relatively new crop of sweet sorghum), sweet sorghum becomes viable option with assured incomes for cultivation under dryland conditions for smallholder farmers.